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Gauss–Bonnet gravitational baryogenesis

S.D. Odintsov [a,b,c], V.K. Oikonomou [d,e,*]

[a] Institute of Space Sciences (IEEC-CSIC), Campus UAB, Carrer de Can Magrans, s/n 08193 Cerdanyola del Valles, Barcelona, Spain
[b] ICREA, Passeig Lluís Companys, 23, 08010 Barcelona, Spain
[c] Institute of Physics, Kazan Federal University, 420008 Kazan, Russia
[d] Tomsk State Pedagogical University, 634061 Tomsk, Russia
[e] Laboratory for Theoretical Cosmology, Tomsk State University of Control Systems and Radioelectronics (TUSUR), 634050 Tomsk, Russia

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A B S T R A C T

In this letter we study some variant forms of gravitational baryogenesis by using higher order terms containing the partial derivative of the Gauss–Bonnet scalar coupled to the baryonic current. This scenario extends the well known theory that uses a similar coupling between the Ricci scalar and the baryonic current. One appealing feature of the scenario we study is that the predicted baryon asymmetry during a radiation domination era is non-zero. We calculate the baryon to entropy ratio for the Gauss–Bonnet term and by using the observational constraints we investigate which are the allowed forms of the $R + F(\mathcal{G})$ gravity controlling the evolution. Also we briefly discuss some alternative higher order terms that can generate a non-zero baryon asymmetry, even in the conformal invariance limit.

1. Introduction

The excess of matter over antimatter in our Universe is one of the unsolved mysteries in cosmology, ever since cosmology became an autonomous research branch. The observational data coming from the Cosmic Microwave Background [2], supported by the Big Bang nucleosynthesis successful predictions [1], indicate an excess of matter over antimatter, and every viable cosmological description should in some way explain this excess in a successful way. One theoretically appealing mechanism for generating the baryon–anti-baryon asymmetry was given in Ref. [3], which was called as the "gravitational baryogenesis" mechanism. Later on, this mechanism was further studied and developed in Refs. [4–8]. The gravitational baryogenesis mechanism makes use of one of the Sakharov criteria [9], and the baryon–anti-baryon asymmetry is guaranteed by the presence of a $\mathcal{CP}$-violating interaction, which is of the form,

$$\frac{1}{M_*^2}\int d^4x\sqrt{-g}(\partial_\mu R)J^\mu . \tag{1}$$

The term (1) can occur in the theory from higher order interactions coming from an underlying effective theory that controls the high energy physics. The parameter M_* in (1) denotes the cutoff scale of the underlying effective theory, while J^μ, g and R stand for the baryonic matter current, the trace of the metric tensor and the Ricci scalar respectively. In effect, for a flat Friedmann–Robertson–Walker (FRW) Universe, the baryon to entropy ratio η_B/s is proportional to $\dot{R}$. Notably, in the case that the matter fluid content of the flat FRW is controlled by relativistic matter with equation of state parameter $w = 1/3$, the net baryon asymmetry generated by the term (1) is zero.

The purpose of this letter is to investigate the consequences of a baryon asymmetry term related to other curvature invariants and specifically related to the Gauss–Bonnet invariant $\mathcal{G}$, which often appears in string-inspired gravities. Also we shall briefly discuss the effect of baryon asymmetry generating terms related to other higher order gravity terms. For the Gauss–Bonnet case, the $\mathcal{CP}$-violating interaction that will generate the baryon asymmetry of the Universe is of the form,

$$\frac{1}{M_*^2}\int d^4x\sqrt{-g}(\partial_\mu \mathcal{G})J^\mu . \tag{2}$$

This kind of terms can possibly occur in higher order gravities coupled with fundamental group fermion currents. As we demonstrate, for the Gauss–Bonnet baryon asymmetry term (2), there are differences in the resulting baryon to entropy ratio and in addition, the latter is non-zero even in the case that the Universe is filled with relativistic matter ($w = 1/3$). We shall investigate the cases that the Universe evolution is controlled by a matter fluid with

* Corresponding author.
E-mail addresses: odintsov@ieec.uab.es (S.D. Odintsov), v.k.oikonomou1979@gmail.com (V.K. Oikonomou).

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